



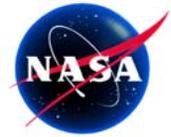
GEO-CAPE

Technology Investments



Mission and Payload:

GEO-CAPE consists of three instruments in geosynchronous Earth orbit near 80°W longitude: a **UV-visible-near-IR wide-area imaging spectrometer** (7-km nadir pixel) capable of mapping North and South America from 45°S to 50°N at about hourly intervals, a **steerable high-spatial-resolution (250 m) event-imaging spectrometer** with a 300-km field of view, and an **IR correlation radiometer** for CO mapping over a field consistent with the wide-area spectrometer. The solar backscatter data from the UV to the near-IR will provide aerosol optical depth information for assimilation into aerosol models and downscaling to surface concentrations. The same data will provide high-quality information on NO₂ and formaldehyde tropospheric columns from which emissions of NO_x and volatile organic compounds, precursors of both O₃ and aerosols, can be characterized. Combination of the near-IR and thermal-IR data will describe vertical CO, an excellent tracer of long-range transport of pollution. The high-resolution event imager would serve as a multidisciplinary programmable scientific observatory and an immediate-response sensor for possible disaster mitigation. The data from the high-resolution event-imaging spectrometer would be coupled to the data generated by the wide-area spectrometer through on-board processing to target specific events (such as forest fires, releases of pollutants, and industrial accidents) where high-spatial-resolution analysis would provide benefits. A substantial fraction of its time would be made available for direct support of selected aircraft and ground-based campaigns or special observing opportunities.



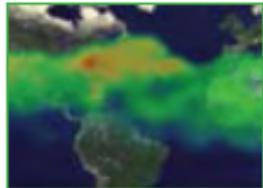
Mission Overview

- Mission Description:
 - Atmospheric gas columns for air quality forecasts;
 - ocean color for coastal ecosystem health and climate emissions
- Instruments:
 - High-spatial-resolution hyperspectral spectrometer
 - Low-spatial-resolution imaging spectrometer
 - IR correlation radiometer

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GEOSTATIONARY COASTAL AND AIR POLLUTION EVENTS (GEO-CAPE)

Launch: 2013-2016 Mission Size: Medium



Identification of human versus natural sources of aerosols and ozone precursors



Dynamics of coastal ecosystems, river plumes, and tidal fronts



Observation of air pollution transport in North, Central, and South America



Prediction of track of oil spills, fires, and releases from natural disasters



Detection and tracking of waterborne hazardous materials

Coastal health



Forecasts of air quality

ESTO Technology Development in Support of Sentinel Multispectral Atmospheric Composition Measurements

Infrared



Missions Supported: ACE, GACM, GEO-CAPE

Measurement Approach

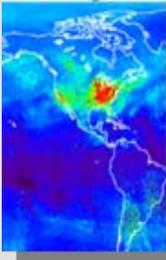
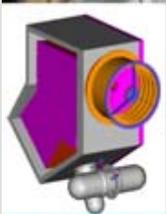
An infrared spectrometer that accurately measures ozone from LEO and GEO

Earth Science Technology Office (ESTO) Investments

- Completed 2nd instrument technology advancement of SIRAS-G, a WFOV, multi-grating/channel IR spectral imager concept designed for LEO or GEO. Lab demonstrated fully functional imaging MWIR spectrometer (3.35-4.8 micron) operating at cryogenic temperatures. (T. Kampe- IIP2 & IIP3)
- Developing TIMS, a miniaturized InfraRed Grating Mapping Spectrometer for space-based global mapping of carbon monoxide (CO) profiles in the troposphere (Kumer – IIP4)
- Development and demonstration of multi-disciplinary frameworks and observation simulations of an adaptive measurement strategy on a sensor web for rapid air quality assessment. (Lee/JPL - AIST05)
- Development of the Adaptive Sky Cloud Science Sensor Web simulation for global atmospheric cloud monitoring. (Burl/JPL - AIST05)
- Developed and ground-demonstrated a multispectral imaging airborne Fabry-Perot interferometer (FPI) system designed for geostationary observations. The concept observes a narrow interval within the 9.6 micron ozone infrared band with a spectral resolution $\sim 0.07 \text{ cm}^{-1}$, and also has applicability toward measurement of other trace species (A. Larar-IIP1)
- Characterization of lab prototype of the SWIR (2.3 μm) subsystem of an infrared gas filter correlation radiometer for GEO CO measurements (Neil/LaRC-IIP07)
- Development and demonstration of high-speed, high-dynamic range CMOS hybrid focal plane arrays (FPAs), and parallel, co-aligned optical trains for UV/V/NIR, and mid-IR bands of (PanFTS) instrument (Sander/JPL-IIP07)

Future Technology Investment Areas

- Further development of SIRAS-G subsystem technologies (focal plane arrays, scan mirror, and calibration subsystems) prior to integration into prototype
- Complete 4-channel SIRAS-G system EM and fully characterize the performance of the instrument in airborne demonstrations
- SIRAS-G instrument prototype
- SIRAS-G IR Grating Spectrometer EM build and field demonstration
- TIMS field demonstration and airborne demonstration
- Modify and demonstrate TIMS components operation @ 9.6 and 3.57 μm , and in the NO₂ and aerosol sensing regions of the visible
- Demonstrate a 2-channel TIMS
- Build an expanded TIMS EM utilizing multi-channel mapping spectrometers with measurement capabilities @ 9.6 μm (tropospheric O₃ profiles), @ 3.57 μm (near surface O₃ and HCHO), @ 2.3 and 4.65 μm (CO) and in VIS regions suitable for NO₂ and aerosol
- Knowledge management (capture, representation, categorization and use of Earth science knowledge)
- Goal-directed science data management (e.g., automatically task sensor web components to reconfigure for on-demand event or model predictions)
- Fabry-Perot Interferometer EM build and field demonstration (i.e., mountain top and/or aircraft deployment); system enhancements/optimizations to improve radiometric, spatial, and spectral fidelity; continued laboratory characterization testing
- Detectors, SCS optics, image stabilization and knowledge system
- CO Detector - Radiation hard high performance electronics (ADC, FPGAs, solid state storage, etc) – Enhancing
- Bring CMOS detectors to TRL 5/6 for TROPI
- CO Detector - Light weight thermal control and structural materials – Enhancing





ESTO Technology Development in Support of Global Ocean Carbon, Ecosystems, & Coastal Process Measurements

Missions Supported: ACE, GEO-CAPE

Measurement Approach

- LEO UV-VIS spectrometer
- GEO high resolution hyperspectral imager

Earth Science Technology Office (ESTO) Investments

- Developed and partially demonstrated a multi-spectral imager for oceanographic imaging applications. The concept is based on implementing a surface plasmon tunable filter (SPTF) with a CMOS imager (B. Pain - ATIP-99)
- Demonstrated a full-scale breadboard dual spectrograph with sensitivities in the UV/VIS (310-481 nm) and the VIS/NIR (500-900 nm) for geostationary observations (S. Janz - IIP-02)
- Development of a tele-supervised adaptive ocean sensor fleet for improved in-situ study of harmful algal blooms, coastal pollutants, oil spills, and hurricane factors (Dolan - AIST-05)
- Development and installation of a prototype gateway between the Digital Oceanographic Data System (DODS) and Web Mapping Servers (WMS) to enable access to Earth science data (P. Cornillon - AIST-QRS-01)
- Development and demonstration of a low cost, reusable, autonomous ocean surface platform to collect ocean-atmosphere data and distribute it in real-time as part of a sensor web (T. Ames - AIST-QRS-01)
- Development and implementation of on-board data reduction and cloud detection methodologies to reduce communication bandwidth requirements (J. LeMoigne - AIST-02)
- Development of a spatiotemporal data mining system for tracking and modeling ocean object movement (Y. Cai - AIST-QRS-04)
- Design and development of an integrated satellite, underwater and ocean surface sensor network for ocean observation and modeling (P. Arabshahi - AIST-05)
- Development and integration of model-based control tools for mobile and stationary sensors in the New York Harbor Observation and Prediction System sensor web (A. Talukder - AIST-QRS-06)

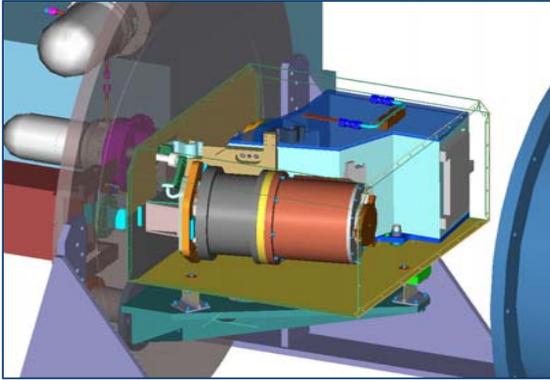
Future Technology Investment Areas

- Develop an SPTF & low-power high sensitivity broadband CMOS imager with accurate wavelength control over entire spectral region.
- Integrate and test multi-spectral device with appropriate optics
- Optimize stray light performance and detector performance of GeoSpec,
- investigate long term stability/performance
- GeoSpec aircraft demo will require some repackaging
- Autonomous in-situ data collection and management
- Image Stabilization and knowledge system
- Aspheric Single Crystal Silicon fabrication and test to advance to TRL 6 for GEO-CAPE
- System modeling and design for GEO-CAPE steering mirror control feedback
- Improving read noise on detector subsystem and detector optimization for specific full-well requirements
- Demonstration with subset of channels with a simple telescope in an aircraft demonstration

Uppelante 6-11-08

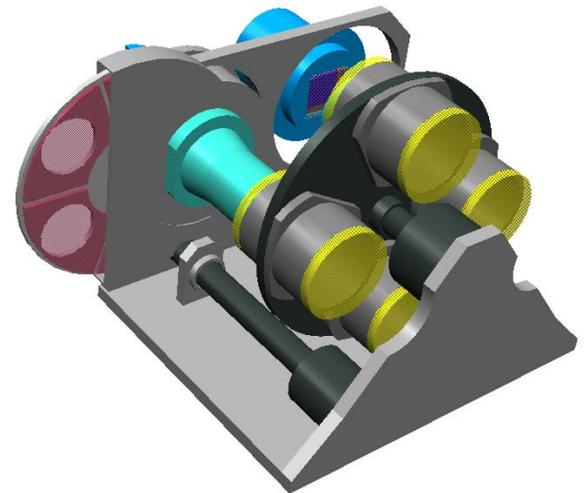


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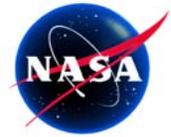
Instrument Technologies

(Current and Completed ESTO Investments)



Infrared Correlation Radiometer Description

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Infrared Correlation Radiometer for GEO-CAPE

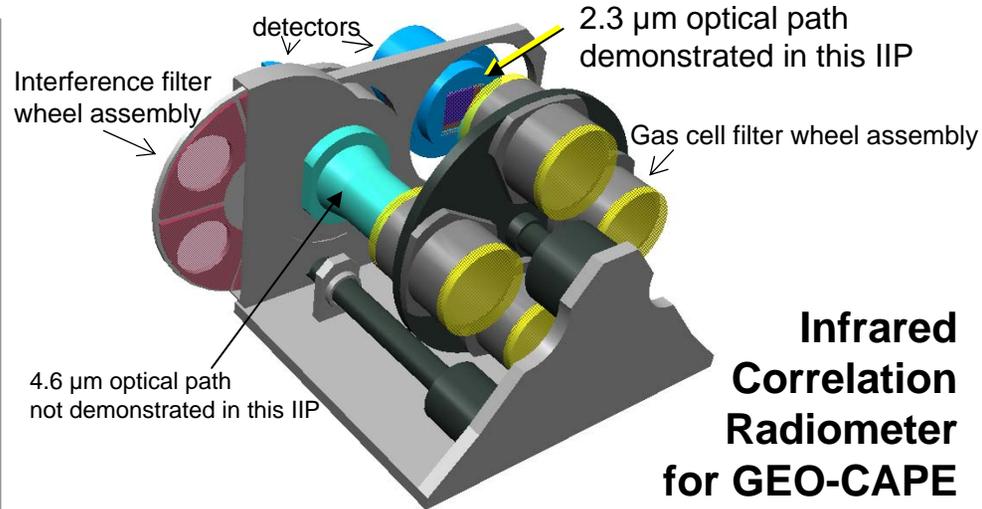
PI: Doreen Neil / NASA Langley

Objective

Characterize the noise and spectral performance of a laboratory prototype of the SWIR (2.3 μm) subsystem of an infrared gas filter correlation radiometer for geostationary carbon monoxide (CO) measurements.

Verify the instrument model to guide evolving GEO-CAPE mission implementation decisions.

Measurements at both 2.3 μm and 4.6 μm are required to obtain boundary layer CO. The Decadal Survey refocused tropospheric chemistry goals toward the lowest layers of the atmosphere, placing new emphasis on the 2.3 μm measurements.



Approach:

Fabricate the 2.3 μm subsystem of an infrared gas filter correlation radiometer specifically designed for geostationary measurements.

Characterize performance to quantify instrument response functions (spectral, spatial, radiometric, and polarization), and explicitly, an end-to-end noise performance characterization.

Incorporate these characterizations into the CO measurement modeling system for use in GEO-CAPE mission formulation and payload system engineering.

CoIs: Jack Fishman, William Luck NASA LaRC, David Edwards NCAR, Lackson Marufu UMD

Key Milestones

- Requirements, design, fabrication 01/10
- Build and Characterizations 10/10
- Integrated system model and documentation 01/11

TRL_{in} = 3

PanFTS Description

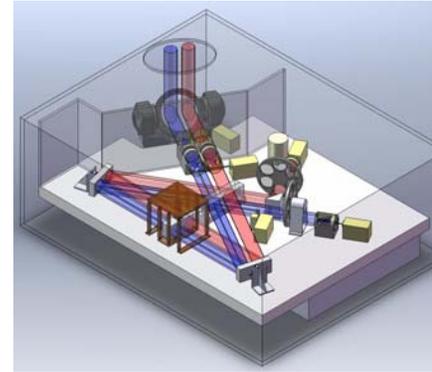


Panchromatic Fourier Transform Spectrometer (PanFTS) Instrument for the GEO-CAPE Mission

PI: Stanley P. Sander / JPL

Objectives:

- Define a science plan for the GEO-CAPE mission which makes use of the enhanced vertical profiling capability of imaging Fourier Transform Spectroscopy (FTS) over the 0.25 - 15 μm spectral range.
- Develop a lab PanFTS instrument which demonstrates two key enabling technologies: high-speed, high-dynamic range CMOS hybrid focal plane arrays (FPAs), and parallel, co-aligned optical trains for the ultraviolet-Visible-Near-infrared (UV-Vis-NIR), and mid-IR bands.
- Verify the performance of PanFTS by acquiring and analyzing atmospheric spectra from JPL's California Laboratory of Atmospheric Remote Sensing (CLARS).



PanFTS Specs (for flight)	
Characteristic	Value
Size	130 x 100 x 50 cm
Mass	150 kg
Power	120 W
Data rate	150 MB/s
Field of view	± 7.3 deg. off-nadir
Pointing required	~ 1 arcsec
Operational lifetime	5 years

PanFTS mechanical layout and flight instrument specs

Approach:

- Develop detailed instrument design specifications on FPAs, FTS scan mechanism and interferometer optics
- Issue Request for Information to industry for FPA detectors and electronics
- Verify scan mechanism by life testing
- Procure key components, build/test lab instrument
- Field deployment/test at CLARS Facility

Co-Is:

- R. Beer, J-F Blavier, K. Bowman, A. Eldering, D. Rider, G. Toon, W. Traub, J. Worden (JPL)
- Task Manager: R. Key (JPL)

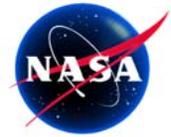
Key Milestones:

- Complete instrument requirements definition 09/08
- Complete instrument design 03/09
- Deliver UV FPA 12/09
- Deliver IR FPA 04/10
- Deliver Scan Mechanism 10/09
- Complete instrument assembly 07/10
- Complete field testing at CLARS Facility 06/11

TRL_{in} = 3

TIMS Description

- **Tropospheric Infrared Mapping Spectrometer (TIMS) that would provide considerably improve measurements of CO, commensurate with the NRC report requirements. Nadir radiance acquired at high spectral resolution, on the order of a few tenths cm^{-1} , in the regions of the CO bands near 2.3 microns (solar reflective, SR) and 4.7 microns (thermal emissive, TIR), together with the low noise design (signal photon statistics dominated) would provide for CO retrieval with improved vertical information, including the lowest several km (boundary) layer. The primary measurement goal is CO, but the spectra contain information that facilitates retrieval of column CH_4 , and H_2O partial columns including considerable improvement in the boundary layer.**
- **The technology uses low noise 2D arrays fed by a grating spectrometer. There are no moving parts. The design is compact and facilitates, if desired, added spectral regions for measurements of additional species , e.g., in the 3.6 and 9.6 micron bands for altitude resolved measurements of tropospheric ozone partial columns and for much improved formaldehyde (HCHO) total column.**



Tropospheric Infrared Mapping Spectrometers (TIMS) for CO

PI: Jack Kumer, Lockheed Martin

Objective

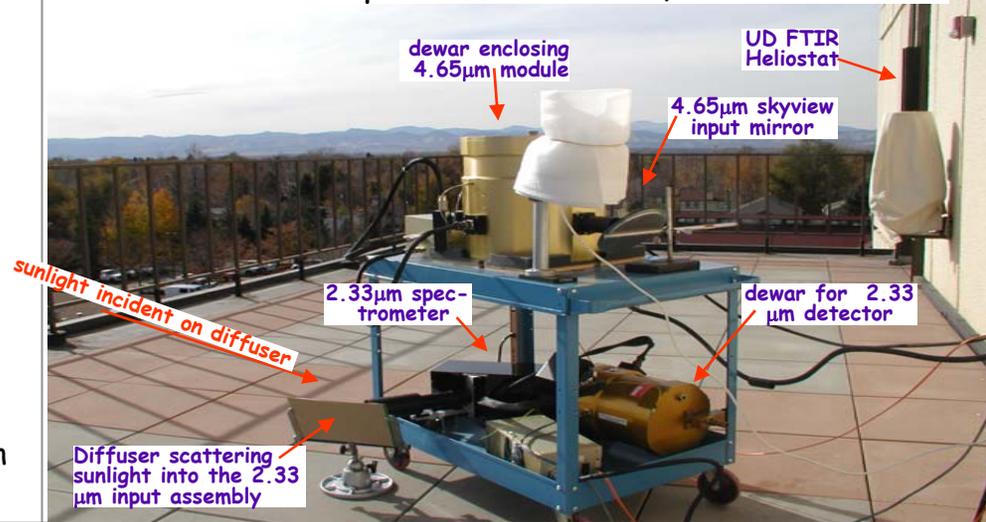
- Demonstrate technology which will enable space-based global mapping of carbon monoxide (CO) profiles in the troposphere
- Develop NIR and MWIR portable brassboard spectrometers with required spectral resolution and sensitivity
- Demonstrate ability to acquire high quality atmospheric spectra in ground-based tests
- Validate retrieval of CO profiles from spectra through comparison with Denver University Fourier transform infrared spectroscopy (FTIR) measurements
- Develop concepts for flight instrument design, operation and data production.

Approach

- Perform brassboard development of 4.65 and 2.33 μm GMS modules.
- Perform ground-based acquisition of atmospheric spectra.
- Validate retrieval by simultaneous operation with a calibrated Fourier Transform Spectrometer (FTS) from Univ. of Denver.
- Develop a flight instrument design concept recommendation.

Co-Is: AE Roche, JL Mergenthaler, Lockheed; F Murcray, U. of Denver; L Strow, U. Maryland; R Chatfield, NASA ARC.

TIMS & FTIR data acquisition @ Denver Univ, Nov 2007



Key Milestones

- Complete development & functional tests of 4.65 μm module. 12/06
- Performance test/calibrate 4.65 μm module.
- Complete development/test/calibration of 2.33 μm module. Field measurement campaign: TIMS vs UD spectra & retrieval 12/07
- Validate CO profile retrieval from ground field campaigns. Flight instrument design concepts, data product generation concepts 12/08

GeoSpec Description

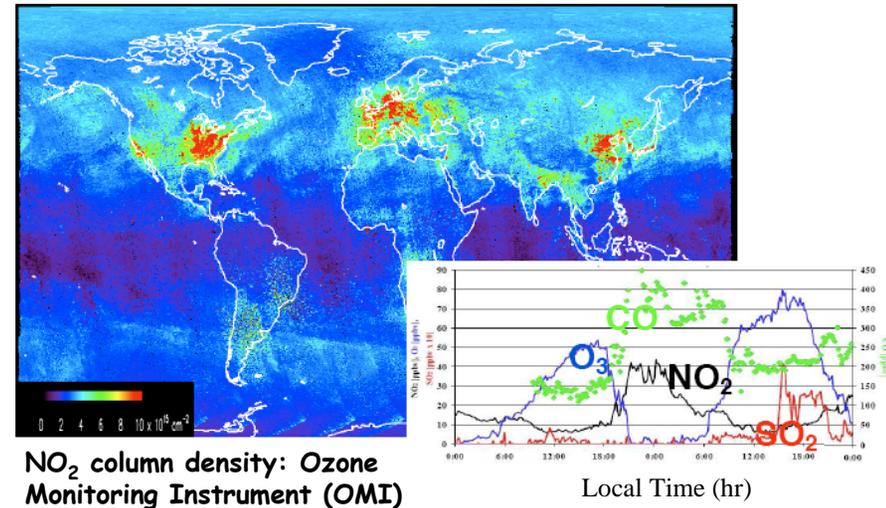


Geostationary Spectrograph (GeoSpec) for Earth and Atmospheric Science Applications

PI: Dr. Scott Janz / GSFC

Objective

- Demonstrate the feasibility of future Geostationary Earth Science missions using hyperspectral UV/VIS/NIR instrumentation.
- Geostationary orbit allows the measurement of the diurnal evolution of physical processes.
- Breadboard demonstration of a dual spectrograph instrument with UV/VIS and VIS/NIR channels using hybrid PIN/CMOS detectors.
- Target Earth Science Products: Coastal and ocean pollution events, tidal effects, origin and evolution of aerosol plumes, and trace gas measurements of O₃, NO₂, CH₂O, and SO₂.



Accomplishments:

- Completed GeoSpec instrument design and system performance studies including polarization sensitivity, spectral sampling/sensitivity trades, image quality, and detector packaging/thermal control.
- Completed design, testing, fabrication and coating of all system optics including convex holographic gratings and new technology single crystal silicon (SCS) mirrors.
- Completed design and fabrication of optical bench mechanical structure.
- Completed optical alignment and end-to-end testing of breadboard including atmospheric retrievals. • Completed both ISAL and IMDC studies of flight instrument concept.

CoIs:

- Pennsylvania State University
- Washington State University
- Research Support Instruments/Ball Aerospace

TRL_{in} = 3 TRL_{out} = 4



SIRAS-G Description

- SIRAS-G provides a compact, low mass solution for imaging IR spectrometers exhibiting low spectral smile and keystone distortion suitable for future Earth science needs.
- SIRAS-G technology is ideally suited for measuring atmospheric temperature, water vapor, trace gases and dust aerosol from satellite, providing high-spectral resolution imaging spectroscopy over a broad IR spectral range and extended field of view.
- Instrument concepts developed for future mission in LEO and GEO. One such instrument concept flown in LEO has the potential to provide improved spatial resolution, comparable to that of MODIS that would improve the yield of cloud-free pixels and tracking of the transport trace gases.
- The SIRAS-G dispersive spectrometer module is readily adaptable for missions in LEO, GEO and MEO orbits and can be optimized for spectral resolution over subsets of the total spectral range.
- Completed the 3-year SIRAS-G IIP development effort, including successful testing of the demonstration instrument at cryogenic temperatures.
- The performance of the demo instrument has been quantified including measurement of keystone distortion, spectral smile, MTF, and the spectral response function (SRF) to high accuracy using novel test methodologies developed at BATC.

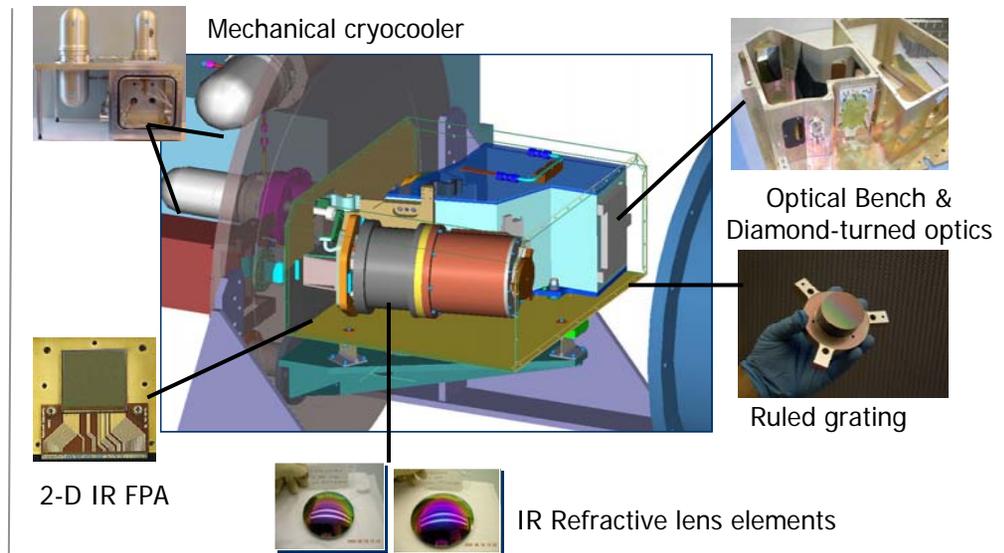


SIRAS-G, the Spaceborne Infrared Atmospheric Sounder for GEO

PI: Thomas Kampe, Ball Aerospace & Technologies Corp. (BATC)

Objective

- Develop instrument technology for IR atmospheric sounding from GEO and LEO
- Validate operational performance in a laboratory demonstration
- Generate a design recommendation for space flight instrument



Accomplishment

- Developed single-channel MWIR lab demo that integrates flight-like spectrometer, active cooling, flight-like IR Focal Plane Arrays and electronics
- Spectrometer design developed for low distortion (spectral smile & keystone) & excellent image quality. Design form is extendable to multi-leg configuration (3-15 μm spectral coverage)
- Advanced technology multi-stage warm shield concept demonstrated
- Tested demo instrument in cryogenic environment using test methodology and apparatus developed at BATC (keystone distortion, smile, MTF, SRF, dispersion)

Technology Development Partners

Bill Folkner/Jet Propulsion Laboratory

TRLin= 2 TRL current= 4



WFIS Description



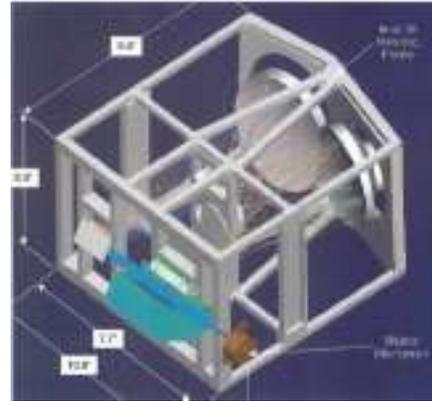
Wide Field Imaging Spectrometer (WFIS)

PI: Randy Pollock at Hamilton-Sundstrand

Objectives

- Perform the final design iteration and test an engineering model of the WFIS to study atmospheric chemistry, clouds, and aerosols
- Build a hyperspectral instrument with limb-to-limb viewing and 1 km resolution
- Reduce size, weight, and power over similar current instruments
- Obtain airborne test data

Concept Design



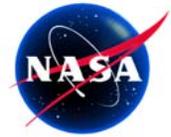
Accomplishments

- Demonstrated optomechanical portions of WFIS in a laboratory environment.
- Completed optomechanical design to near flight standards.
 - Meet materials requirement for vacuum pressure and vibration (weight ~6.8Kg, size (22x18x33cms),
- Measurements of the geometric distortion of the optical system look promising.
- Simple modifications to the present work indicate that all the performance requirements for atmospheric chemistry and clouds/aerosol science can be demonstrated with the WFIS EM.

Co-Is: Warren Wiscombe, Yoram Kaufman,
Pawan Bhartia, GSFC

TRL_{in} = 3 TRL_{out} = 5

Multi-Spectral CMOS Description

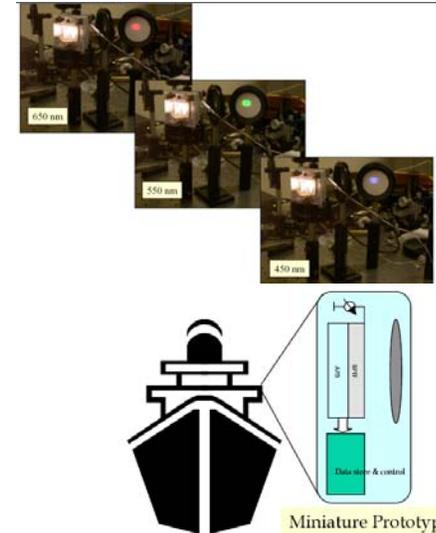
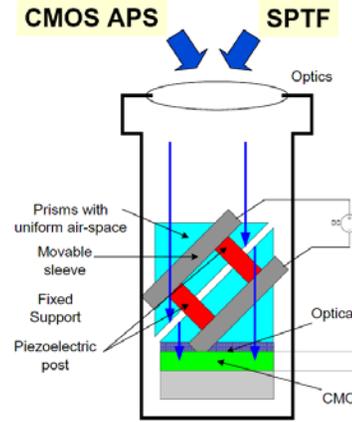


Multi-Spectral Staring CMOS Focal-plane Array for Oceanographic Imaging Applications

PI: Mithu Pain, JPL

Objectives

Develop an advanced, low-cost, compact, high-resolution, staring multi-spectral digital focal-plane array (FPA) based on demonstrated CMOS Active Pixel Sensor (APS) and Surface-Plasmon-Tunable-Filter (SPTF) technologies. The instrument component will find use in Oceanography and Meteorology, atmospheric chemistry, cloud studies, aerosol studies, studies relating to vegetation recovery, volcanic ash characteristics, flood characterization, and land-cover usage and changes.



Accomplishments

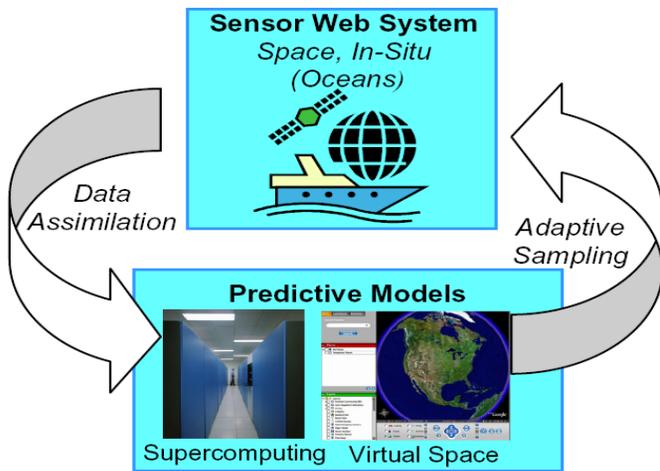
Developed a new multi-spectral imager by integrating a Surface-Plasmon-Tunable-Filter (SPTF) with a CMOS imager.

- Unlike other spectral devices, this unit operates in a spectral-sequential manner, providing output at one wavelength over the entire field-of-view.
- The center-frequency (or wavelength) can be changed across the entire visible band and is tunable on-the-fly by changing the applied voltages on the SPTF.
- The instrument is small and compact (<100 gm, < 1inch³) and is low-power (<100 mW) due to the use of a CMOS imager and due to the absence of any d.c. current draw by the SPTF.

Developed a megapixel imager with superior performance compared to previous generation in terms of cross-talk, noise, linearity, and signal handling capacity.

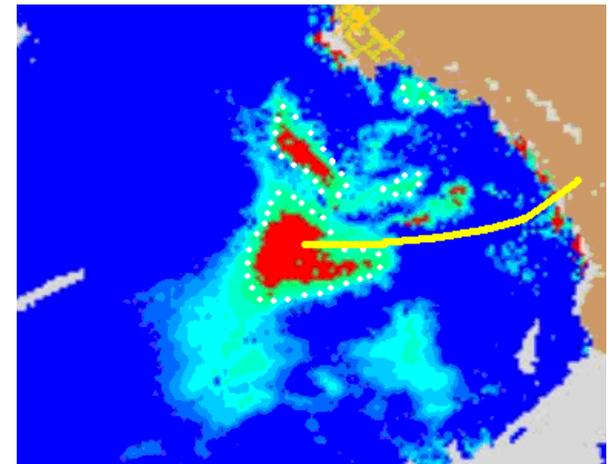
TRL_{in} = 3 TRL_{out} = 4

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Information Systems Technologies

(Current and Completed ESTO Investments)



SOX Description

- **The goal of the Sensor-web Operations Explorer (SOX) is to provide an advanced observation system simulation experiment (OSSE) capability for the global and regional Earth atmospheric science community.**
- **A three-step approach has been devised to achieve the goal. The first step is to develop a flexible concept design exploration space for sensor-web system architectures and operational scenarios.**
- **The second step is to develop a science impact metric that can be applied to quantitatively evaluate science-return from the explored system architectures and operational scenarios.**
- **The final step is to establish a process that coordinates interdisciplinary collaboration between scientists and engineers to develop optimal observation scenarios.**

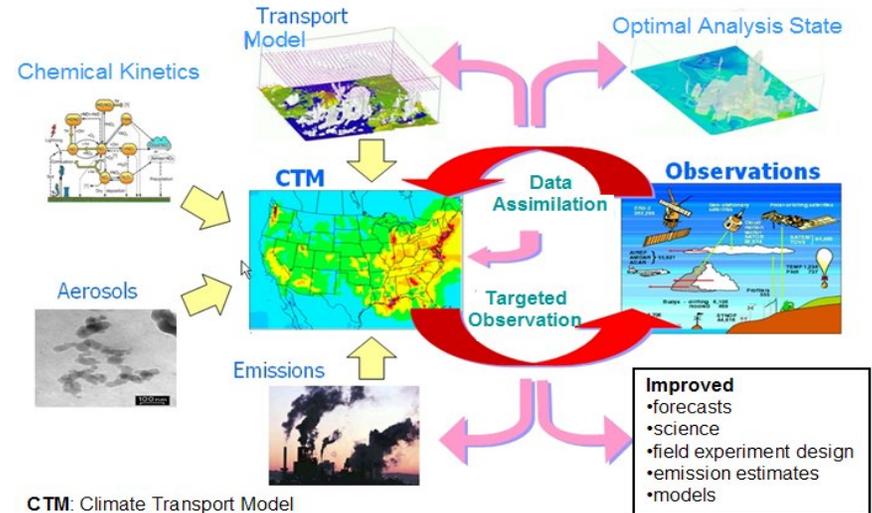


Sensor-Web Operations Explorer (SOX)

PI: MeeMong Lee, JPL

Objective

- Enable adaptive measurement strategy exploration on a sensor web for rapid air quality assessment.
- Provide a comprehensive sensor-web system simulation with multiple sensors and multiple platforms.
- Provide quantitative science return metric that can identify where and when specific measurements have the greatest impact.
- Provide collaborative campaign planning process among distributed users.



SOX Optimizes Observation Strategies for Air Quality Information Content

Approach

- Develop multi-disciplinary frameworks and link observation simulations, reference models, science retrieval and analysis algorithms, data assimilation software, forecasting code, and assessment code.
- Develop scalable system modules with asynchronous interface protocols and create a "system of systems" providing flexible system configuration and operation.

Key Milestones

- SOX software Architecture Design 12/06
- SOX Interface Definitions 2/07
- SC-borne Sensor-web Ops. Explorer 9/07
- Air-borne Sensor-web platform simulation 3/08
- Dual platform campaign planner 9/08
- In-situ platform simulation 3/08
- Multi-platform campaign planner 6/09
- Complete SOX system 9/09

TRL_{in} = 3 TRL_{current} = 4



Co-I's/Partners

- Charles Miller, Kevin Bowman, Richard Weidner (JPL)
- Adrian Sandu (Virginia Polytechnic)

Adaptive Sky Description

- **Adaptive Sky is an ESTO-funded Advanced Information Systems Technology activity that is developing software to enable multiple sensing assets to be dynamically combined into sensor webs.**
- **The ASky feature correspondence toolbox consists of a variety of methods for automatically relating the observations of one instrument at time t to the observations of another instrument at time t' .**
- **A key end product from this task will be the ability to generate object-centric datasets in which observations from multiple satellite and in-situ assets are organized not merely by the instrument packaging scheme (e.g., granules, blocks, images, swaths) or by spatial-temporal address (lat, lon, time), but by association with particular physical objects or processes.**
- **We have produced an early demonstration of this concept combining selected Adaptive Sky components to identify, track, and reacquire volcanic ash clouds generated by the October 2007 eruption of Bezymianny in Kamchatka.**
- **The wide area coverage and high temporal sampling of GOES coupled with ASky tracking capabilities provides a bridge between the less frequent overpasses of NASA's polar orbiting satellites.**
- **With this approach, a rich object-centric dataset including measurements from at least five different instruments on four different spacecraft platforms was generated covering a timespan of approximately 30 hours and movement of the ash clouds over 400km from the eruption site.**

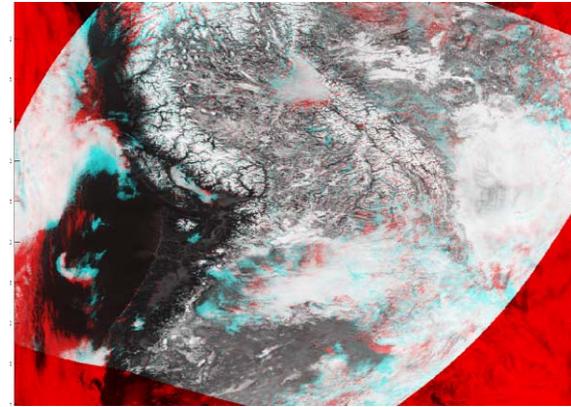


Adaptive Sky

PI: Michael Burl, (JPL)

Objective

- Enable observations from multiple sensing assets (satellites, in-situ sensors, etc.) to be dynamically combined into "sensor webs".
- Develop an efficient, trusted C-language feature correspondence toolbox that serves the sensor web community as LINPACK (LINear algebra PACKage) has served the numerical computing community.
- Demonstrate fusion of multi-instrument observations into novel data products of high scientific value.



Automatic registration between images taken 100 minutes apart with the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on Aqua (cyan) and the twin MODIS instrument on Terra (red).

Accomplishments

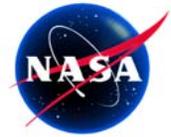
- Detailed scientific use scenarios - Earth Observing System (EOS) match-ups, combining satellite and ground-based cloud imagery, volcanic plume and ash cloud monitoring, Southern California Fires, etc.
- Developed a toolbox that other sensor web projects can use to compare data
- Successful application of techniques to real data:
 - Detection and tracking of clouds in ground imagery using Maximally-stable Extremal Region (MSER) features.
 - Identification and automatic registration of A-Train and Terra coincidences.
 - Automatic stabilization of Geostationary Operational Environmental Satellite (GOES) image sequences.
- Demonstration of multi-instrument fusion within Google Earth - lidar observation of volcanic ash cloud.

CoI: Michael J. Garay (Raytheon)

TRL_{in} = 3; TRL_{out} = 4

TAOSF Description

- **TAOSF supervises and coordinates a group of robotic boats, the OASIS platforms, to enable in situ study of phenomena in the ocean/atmosphere interface, as well as on the ocean surface and sub-surface.**
- **The OASIS platforms are extended-deployment autonomous ocean surface vessels, whose development is funded separately by the National Oceanic and Atmospheric Administration (NOAA).**
- **TAOSF allows a human operator to effectively supervise and coordinate multiple robotic assets using a multi-level autonomy control architecture, where the operating mode of the vehicles ranges from autonomous control to teleoperated human control.**
- **TAOSF increases data-gathering effectiveness and science return while reducing demands on scientists for robotic asset tasking, control, and monitoring.**
- **The first field application chosen for TAOSF is the characterization of Harmful Algal Blooms (HABs).**

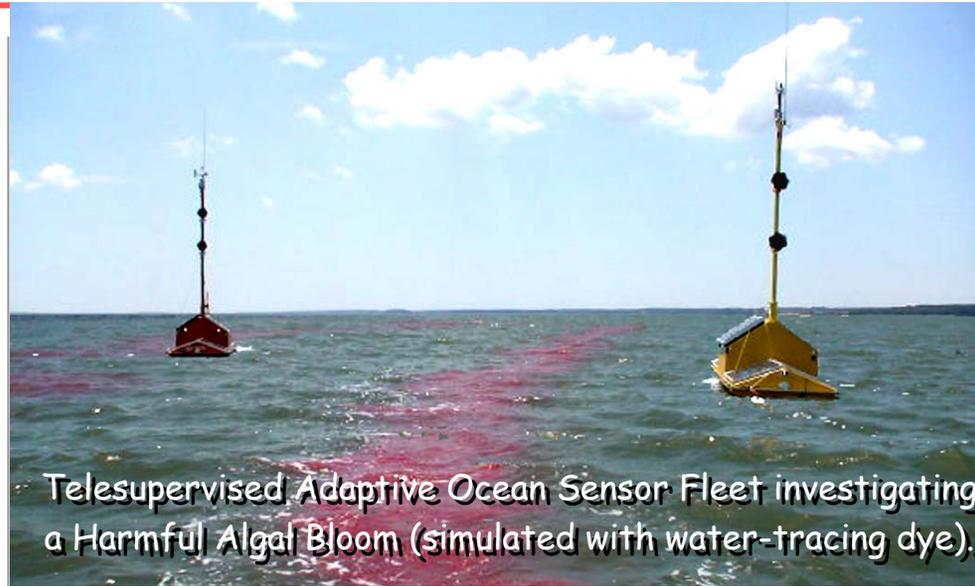


Telesupervised Adaptive Ocean Sensor Fleet (TAOSF)

PI: John Dolan, CMU

Objective

- Improved in-situ study of Harmful Algal Blooms (HAB), coastal pollutants, oil spills, and hurricane factors
- Expanded data-gathering effectiveness and science return of existing NOAA OASIS (Ocean Atmosphere Sensor Integration System) surface vehicles
- Establishment of sensor web capability combining ocean-deployed and space sensors
- Manageable demands on scientists for tasking, control, and monitoring



Approach

- Telesupervision of a networked fleet of NOAA surface autonomous vehicles (OASIS)
- Adaptive repositioning of sensor assets based on environmental sensor inputs (e.g., concentration gradients)
- Integration of complementary established and emergent technologies (System Supervision Architecture (SSA), Inference Grids, Adaptive Sensor Fleet (ASF), Instrument Remote Control (IRC), and OASIS)
- Thorough, realistic, step-by-step testing in relevant environments

Co-I's/Partners

- Gregg Podnar / CMU
- Jeffrey Hosler, John Moisan, Tiffany Moisan / GSFC
- Alberto Elfes / JPL

Key Milestones

- | | |
|--|----------|
| • Interface Definition Document | Feb 2007 |
| • Test components on one platform in water | May 2007 |
| • Autonomous multi-platform mapping of dye | Jul 2007 |
| • Science requirements for Inference Grid | Feb 2008 |
| • Multi-platform concentration search simulation | May 2008 |
| • HAB search in estuary for high concentration | Jul 2008 |
| • Moving-water test plan & identify location | Feb 2009 |
| • Simulate test using in-situ and MODIS data | May 2009 |
| • Use MODIS data to target and reassign fleet | Jul 2009 |

TRL_{in} = 4

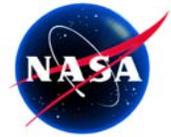
TRL_{EndY1} = 5

TRL_{EndY2} = 6

Ocean Object Movement Modeling Description

The objective of the project is to predicate conditions favorable for an anomalous event to occur where targets have not been observed.

- The team developed a spatiotemporal Bayesian model for predicting the occurrence of ocean surface objects.
- The case study is based on the HAB (harmful algal blooms) database off the coast of Florida.
- The team used the cell count data and the geographical information and occurrence time as historical data.
- Variables also include the satellite images of chlorophyll and anomaly from NASA and data regarding the HAB (salt concentration, wind, cell count, and time).

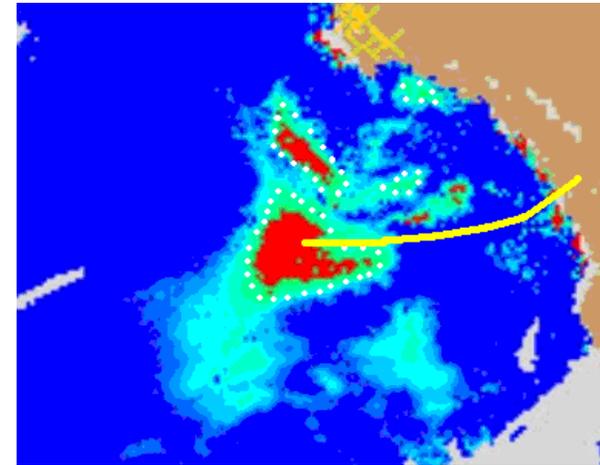


Spatiotemporal Data Mining System for Tracking and Modeling Ocean Object Movement

PI: Yang Cai / Carnegie Mellon University

Objectives

- This project enables more efficient and less time consuming analysis of oceanographic objects, e.g. river plumes and harmful algal blooms, etc.
- To track the movement of ocean objects that have been identified
- To predict the movement of identified objects.



Tracking and prediction of harmful algae

Accomplishments

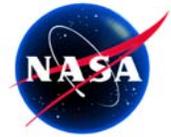
- Completed case studies for tracking the harmful algal blooms and river plumes, using SeaWiFS satellite images
- Completed the prototypes of the spatiotemporal data mining toolbox in MATLAB that can easily be used by field researchers and monitoring institutes
- Developed prototype software for object tracking that can help to monitor the harmful algae across regions and is able to automate the visual oceanography process
- Developed the prediction models that combine images and numerical data sources. Results show that the computer model can process more samples (over 2,384) than human manual process (188) with better accuracy in positive detection and positive accuracy

Co-I/Partner: Co-I, Richard Stumpf, NOAA

TRL_{in} = 4; TRL_{out} = 6

Ocean Observation Sensor Web Description

- **The ocean-observing smart sensor web is composed of both mobile and fixed underwater assets, with EOS satellite data providing larger-scale context.**
- **The team has worked on the development of various network elements:**
- **(1) a cable-connected mooring system with a profiler under real-time control with inductive battery charging;**
- **(2) a glider with integrated acoustic communications and broadband receiving capability;**
- **(3) an integrated acoustic navigation and communication network with tomography on various scales; and**
- **(4) a satellite uplink and feedback system.**

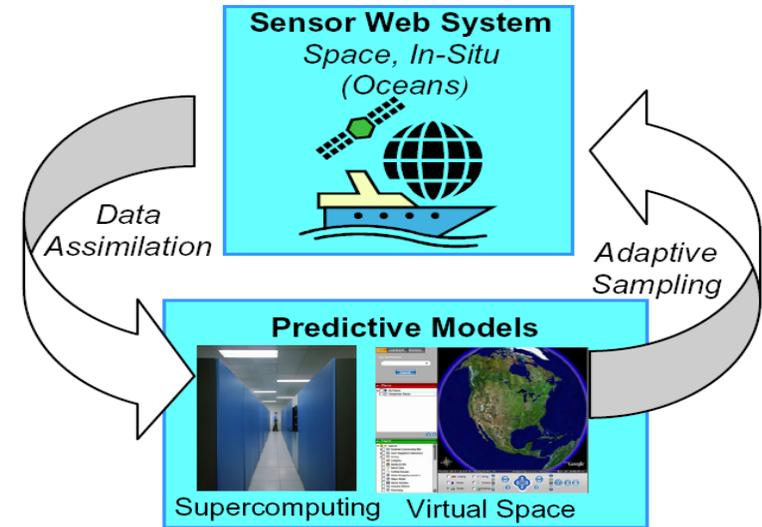


A Smart Sensor Web for Ocean Observation: System Design, Modeling, and Optimization

PI: Payman Arabshahi, University of Washington

Objective

- Design, develop, and test an integrated satellite and underwater acoustic communications and navigation sensor network infrastructure and a semi-closed loop dynamic sensor network for ocean observation and modeling.
- Perform science experiments in Monterey Bay, enabled by such a network, and evolve them to growing levels of sophistication over the period of performance (three years).



Semi-closed loop dynamic smart ocean sensor web architecture

Approach

- Develop a first-of-its-kind ad-hoc multi-hop satellite/acoustic sensor network, with features such as sensor asset reconfiguration, adaptive sampling and autonomous event detection, targeted observation, location-aware sensing, built-in navigation on mobile nodes (Seagliders), and high-bandwidth, high-power observation on cabled seafloor and moored nodes.
- Develop strong tie with NASA satellite oceanography and ocean science community to carry out new experiments which will overcome limitations in current approaches and do in-situ calibration of data gathered via remote sensing by NASA satellites.

Co-Is/Partners

- Andrew Gray / AGCI
- Yi Chao / JPL
- Sumit Roy, Bruce Howe, Warren Fox / U. Washington

Key Milestones

- Acoustic/Satellite Sensor Web
 - Baseline Network 08/07
 - Enhanced Network 08/09
- Field Work at Monterey Bay
 - Deploy mooring and modems 11/07
 - Complete field test with seagliders 11/08
- Data Analysis
 - Interface between sensor and Regional Ocean Modeling System (ROMS) 11/07
 - Data analysis from field work 05/09

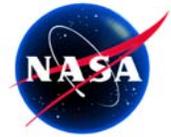
TRL_{in} = 3

TRL_{current} = 3



CARDS Description

- In this AIST-funded project, a novel Model Predictive Control (MPC) framework to adaptively control real-time resources of a variety of static & mobile sensor web assets with limited resources was developed and shown to improve the performance of the New York Harbor Prediction and Observation Sensor Web System (NYHOPS).
- NYHOPS has operated for several years and comprises a network of sensors to monitor coastal and ocean parameters (elevation, salinity, temperature, and water velocity) in the densely populated regions of the Hudson-Raritan Estuary and the New Jersey Atlantic Ocean shoreline. The current NYHOPS sensor web operates in a fixed mode of operation without any adaptation, which is severely limiting for observing and modeling many kinds of spatiotemporal events such as plumes, storm surges.
- MPC assumes a control 'model-based' solution for sensor web adaptation. Determination of the optimal control policy is posed as an optimization problem where the function to be optimized represents the relative utility and cost of performing the control actions. The constraints represent the physical limitations of the system such as energy and wireless network bandwidth. The optimal control policy is obtained by constrained minimization of the objective function at every control step. The predictive capability of the MPC enables a look-ahead capability that considers future states/events to make the current optimal control decision.
- CARDS used the MPC to adapt the overall NYHOPS system, including the sampling rates of static sensors, communication bandwidth, dynamic re-assignment of sensors to relay nodes, and the movement of mobile underwater unmanned vehicles in response to observed events, and thereby improve the accuracy and predictive capability of the ECOMSED model for coastal events including plumes and storm surges. Optimal control of the motions of multiple UUVs guaranteed that the UUV sensor observations had a maximal impact on increasing the predictive power of the ECOMSED model while ensuring that inordinate amounts of energy were not expended in UUV motion. The CARDS sensor web adaptive control solution has been found to improve the accuracy of event modeling and prediction in NYHOPS by 50%. We have developed sensor web visualization tools in Google Earth for use by scientists and customers of the NYHOPS data. CARDS is directly applicable to a variety of sensor webs and paves the way for coordinating multiple ground and space assets owned by NASA for faster and better detection, tracking and characterization of earth and extra-terrestrial environments.



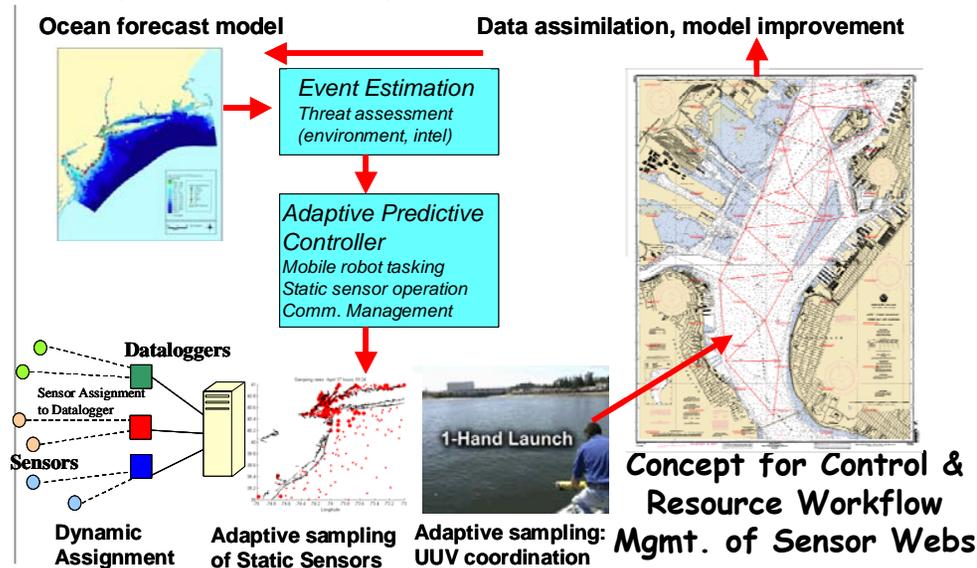
Autonomous In-situ Control and Resource Management in Distributed Heterogeneous Sensor Webs (CARDS)

PI: Ashit Talukder/Jet Propulsion Laboratory

Objective

Design, implement and test model-based control tools in the existing New York Harbor Observation and Prediction System (NYHOPS) sensor web with the following primary task objectives:

- Adaptive in-situ control of multiple resources in heterogeneous spatially distributed sensor webs
- Model based event detection and prognosis from distributed sensor measurements
- Off-line science validation of NYHOPS sensor web operational autonomy and control with CARDS
- Adapt the sensor web to study plumes, coastal storm surges for advanced warning and improved analysis



Accomplishments

- Developed Model Predictive Control framework to adaptively manage real-time resources of a variety of fixed & mobile assets with limited resources to increase predictive power of existing ocean model
- Reduced wireless data transmission costs by 38% using adaptive relay station assignment
- Event detection algorithm designed for unexpected freshwater flow events
- Quantified model uncertainty for use in event detection
- Controlled path of unmanned underwater vehicles so as to maximally increase the utility of their sensor measurements
- Validated above adaptive resource management solution on real coastal NYHOPS sensor web data
- Visualize sensor web data & control outputs in 3-D using Google Earth.
- Implemented Metrics to quantify performance of sensor web control technique

TRL_{in} = 2, TRL_{out} = 4





WMS Gateway to DODS Data Servers

258-90-083

Peter Cornillon, Univ. of Rhode Island

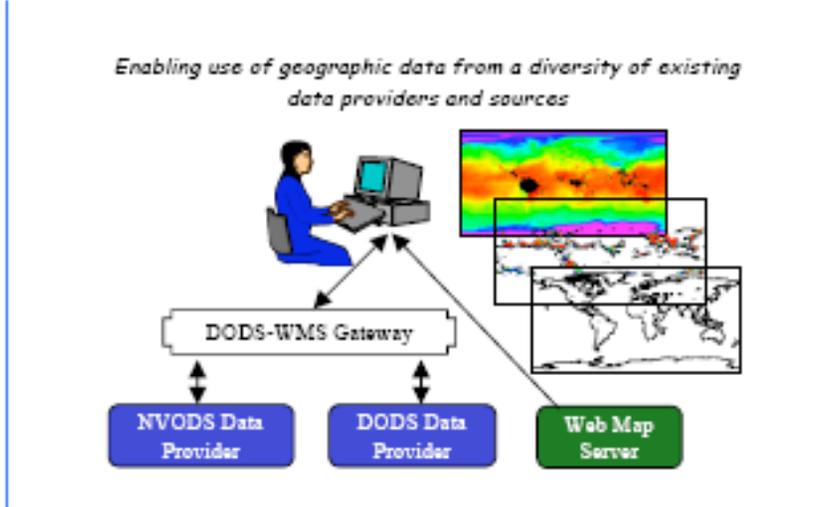
Project Complete FY02

Objective

Enable prototype of gateway between Digital Oceanographic Data System (DODS) and Web Mapping Servers (WMS) to use external 'plug-in' visualization software, to promote data provider participation.

Provide DODS-WMS Gateway in a readily installable form to National Virtual Ocean Data System (NVODS) and DODS data providers sites.

Enable Geographic Information System (GIS) client access to a wealth of existing earth science data.



Accomplishments

Implemented "plug-and-play" modules to enable customization without rebuilding the Gateway.

Plug-and-play modules may be either compiled C++ class specializations or standalone programs.

Merged external plug-and-play configuration information into Gateway's Capabilities XML document.

Enhanced the Capability class to filter the Gateway's Capabilities XML to produce a WMS-1.1.0 compliant Capabilities response.

Built a DODS-GDAL driver for using within the Gateway that can now be used by many other projects.

Schedule and Deliverables

Design interface to plug-in visualizers: Oct. '01

Migrate to OpenGIS Web Mapping Server v. 1.1.0: Nov. '01

Implement of standalone plug-in visualizers: Jan '02

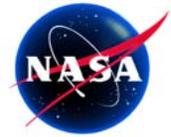
Deliver DODS-WMS Gateway package: **May '02**

No-cost extension for delivery: Sept '02

Projected Infusion
6SFC-DAAC, NVODS (2002+)

Actual Infusion

TRL_{In} = 5 TRL_{Current} = 8 TRL_{Out} = 8

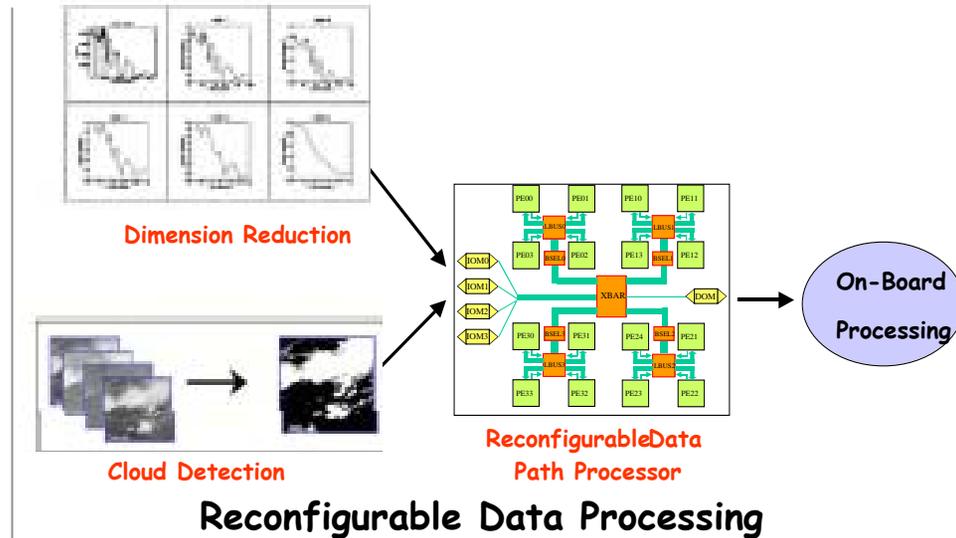


A Reconfigurable Computing Environment for On-Board Data Reduction and Cloud Detection

PI: Jacqueline Le Moigne, GSFC

Objective

- Investigate the use of reconfigurable computing for on-board automatic processing of remote sensing data.
- Use Reconfigurable Data Path Processor/Field Programmable Path Array (RDPP/FPPA), a radiation tolerant alternative to Field Programmable Gate Arrays, developed at NASA/Goddard and U. of Idaho as the computation engine of our study.



Accomplishments

- Performed Algorithms Tradeoff Studies
- Applied and Validated Dimension Reduction to Hyperspectral AIRS Data
- Designed a Flexible FPPA Reconfigurable Processing Testbed ; Designed FPPA Graphical Design Environment
- Performed Algorithm implementation study
- Developed New FPPA Technology Advances/Method & Pilot Software for Accurate Mathematical Computing on Integer Hardware
- Implemented Wavelet-Based Hyperspectral Dimension Reduction on SRC-6: 32X Speedup
- Implemented Automatic Cloud Cover Assessment (ACCA) on SRC-6: 28X Speedup and less than 1% Error Over Water
- Implemented Automatic Image Registration in SRC-6: 4X Speedup

CoIs: P.S. Yeh, J. Joiner, GSFC. W. Xia, GS&T

G. Donohoe & Team, U. Idaho, T. El-Ghazawi & Team, GWU

TRL_{in} = 3; TRL_{out} = 5